GROUPER DENSITY AND DIVERSITY AT TWO SITES IN THE REPUBLIC OF MALDIVES

BY

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ABSTRACT

The density and diversity of shallow-water groupers at Gaagandu, North Male Atoll and Olhugiri, Thaa Atoll, Republic of Maldives was enumerated using visual transects. Four different habitat types were surveyed: reef lagoon, reef crest, reef slope, and a well-developed lagoonal reef. Twenty-two species in seven genera were recorded. Median densities ranged from 7 to 23 grouper 240 m^{-2}. At Gaagandu Island, the reef slope was repeatedly sampled using 20-m belt transects to estimate the efficiency and accuracy of the sampling methodology. Fifteen transects were necessary to estimate the median density of all species within 10% of the reference value and to develop a species list containing 80% of the total number of species observed. The species observed varied in their degree of site attachment. Those species which were most closely tied to their habitat exhibited clumped spatial distributions while those species which 'roamed' over large areas had random spatial distributions. The number of transects necessary to adequately characterize the median density of a species was related to the degree of clumping in its spatial distribution.

INTRODUCTION

Groupers are an important fishery resource throughout the world and are important predators in coral reef ecosystems. Approximately 30 grouper species occur in the Republic of Maldives. Maldivians prefer to eat tuna and have not developed extensive reef fish fisheries (Anderson et al. 1992). Total reef fish catch is approximately 3000 tons per year (Anderson et al. 1992). At present, we are aware of only two operations exploiting groupers, one of which has had little effect on the grouper population (Sluka unpublished data). A market has developed exporting groupers to other southeast Asian countries and to supply many of the resorts located around North Male Atoll. It is therefore likely that reef fish, especially groupers, will come under increasing exploitation in the near future in the Republic of Maldives. Differences in catch

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composition during exploratory fishing were found between a southern atoll (Laamu) and more northern atolls (Alifu and Shaviyani) (Anderson et al. 1992). Shepherd et al. (1992) reported that the abundance and biomass of all species combined was lower on reef flats that were mined than on unmined reef flats. However, the abundance and biomass of fish on slopes adjacent to mined flats was greater than on slopes adjacent to unmined flats. Four grouper species were among the 20 fish which showed the most dissimilarity between these slopes. Cephalopholis miniata and Variola louti had higher biomass on slopes adjacent to mined flats, while Plectropomus pessuliferus and Gracila albomarginata had higher biomass on slopes adjacent to unmined reef flats.

The difficulties in using visual survey methods such as transects has been reviewed by other authors (De Martini and Roberts 1982; Bortone et al. 1986; Sanderson and Solonsky 1986; Greene and Alevizon 1989). Various techniques for solving problems such as transect width (Sale and Sharp 1983), transect length (Fowler 1987), duration of the survey (St. John et al. 1990), and sample size (Sale and Douglas 1981) have been developed. However, these studies usually involved sampling the whole community and in many cases were specifically directed towards sampling patch reefs. Methodologies for surveying serranids were examined by the Great Barrier Reef Marine Park Authority (1979) and Craik (1981) for the Great Barrier Reef region. Groupers are relatively sedentary and site attached. Survey methods must take into account their cryptic behavior and the likelihood of having a patchy or clumped dispersion pattern. This clumped dispersion could lead to misleading results if only a few samples are collected. The number of samples necessary to accurately assess population density will depend on the degree of clumping in their dispersion pattern.

The density and diversity of groupers was studied at two sites in the Republic of Maldives and related to habitat preferences of the different species. The sample size necessary to accurately estimate the density and diversity of groupers in a specific area was examined using visual belt transects.

METHODS

Habitat characterization: The atolls were divided into three habitat zones: 1) lagoon, 2) reef crest, and 3) reef slope. The habitat was characterized by recording the coverage class of dominant substrate (sand, sand-mud, rubble, and hard reef) and lifeforms (seagrass, algae, sponges, octocorals, and hard coral). Substrata and lifeform information were collected by visually estimating the coverage in a belt of 1 m^2 quadrats. Coverage was scored in the following categories: 1) $<$ 10%, 2) 10 - 30%, 3) 30 - 70%, and 4) $>$ 70%. In order to convert to cm^2 the midpoints of each coverage class were summed for each quadrat and averaged.

Visual surveys: Prior to observation, the observer was trained to accurately estimate length using models of fish with a known size-frequency distribution (Bell et al. 1985). Visual surveys were conducted similarly to GBRMPA (1979). A 20-m transect was placed in a haphazard fashion along a particular depth gradient (parallel to shore). An area 6 m out from one side of the transect was intensively searched for all grouper species and then the diver searched the other side in a similar fashion. The number and size of all groupers observed were recorded. Groupers were placed in one of five size categories: <5 cm, 5-15 cm, 15-25 cm, 25-35 cm, and >35 cm. The depth and time of each survey were recorded. All of the habitat zones had similar sampling effort except the reef slope at Gaagandu, which was more intensively surveyed. A distance of approximately 300 m along the reef slope from 6 to 20 m depth was repeatedly sampled in order to assess the number of transects necessary for reliable estimates of density and diversity. Species identifications were made using Heemstra and Randall (1984), Randall (1992), Randall and Heemstra (1991), and Allen and Steene (1987). When information on species identification differed between sources, Randall and Heemstra (1991) was used. Species presence/absense data was collected at Chicken Island, near Gaagandu, for comparison.

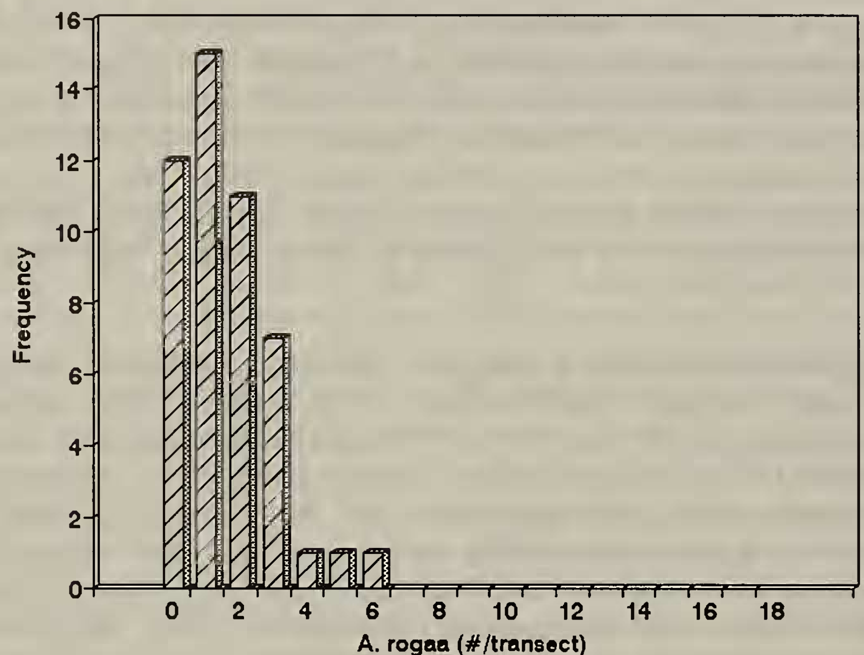
Statistical analysis: Descriptive statistics, histograms, correlations and other calculations were performed using Microsoft Excel® software. The frequency distributions of numbers of groupers observed per transect (240 m^2) exhibited various degrees of skewing to the right (Figure 1a, b). Because of the skewed distributions, medians were considered to characterize the densities better than means. Performance curves based on cumulative medians and species-sample curves were used to determine the number of transect replicates needed to obtain adequate density and diversity estimates for groupers observed in the 48 transects from the slope area (Brower et al. 1990). Medians were compared statistically using a Chi-square procedure (Zar 1984).

For species with median density estimates greater than zero, performance curves were calculated. The performance curves calculated were considered to stabilize when all subsequent cumulative medians fell between the 40th and 60th percentiles calculated from the entire set of 48 transects. The least number of transects required to stabilize the performance curve was considered the number of replicates required for a reliable density estimate. This process was repeated 20 times, with the order of the 48 transects entering the cumulative median calculation being randomized each time. Medians were then calculated from the 20 estimates of replicates required to obtain a reliable density estimate. The median estimates for required replicates were then correlated with the species dispersion pattern using Morisita's Index of Dispersion (I_d) (Brower et al. 1990).

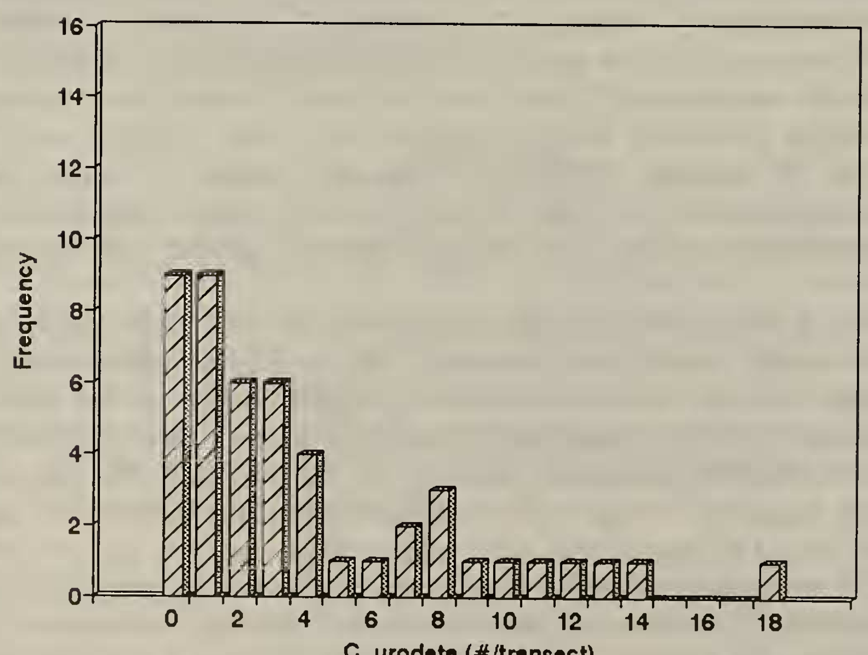
For the density and diversity of all species combined on the reef slope, performance curves and species-sample curves were calculated. The number of replicates required for a stable density estimate was determined in a fashion similar to that noted for individual species except for the criteria used to determine performance curve stability. Instead of using one level for determining stability, i.e. the 40th and 60th percentiles, several levels were evaluated. These levels included 20% of the median (30 and 70 percentiles), 15% (35 and 65 percentiles), 10% (40 and 60 percentiles), and 5% (45 and 55 percentiles). If the median estimated from all 48 transects is considered to be the reference median density, then these different levels for assessing performance curve stability would indicate the accuracy of the median estimated from a given number of transects. The number of replicates based upon the species-sample curves were also

Figure 1: Frequency distribution of number of grouper observed per transect for (a) Aethaloperca rogaa (n=48) and (b) Cephalopholis urodeta (n=48).

a)



b)



assessed at various levels of percent of species observed. The levels included ≥70%, ≥80%, ≥90%, and 100%. This process was repeated 20 times, randomizing the order of the transects each time. Medians were then calculated from the 20 estimates of replicates required for each level of percentage of species observed.

RESULTS

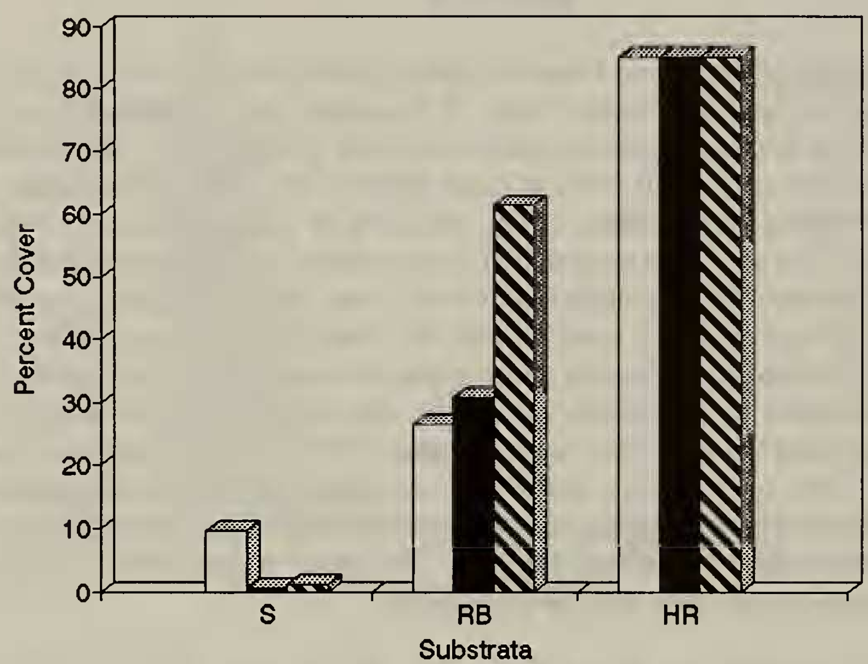
Habitat characterization: Gaagandu Island is located inside the main atoll ring of North Male Atoll. The northern and western sides of the island are surrounded by a lagoon approximately 50 m wide and approximately 2 m deep at high tide. The lagoon was primarily rubble with very small areas of sand (Figure 2a). The rubble areas of the lagoon were covered by turfing algae, had no soft coral or sponges, and very little hard coral (Figure 2b). The reef crest consisted of large, eroded coral heads covered by algal turf. The crest had only slightly higher hard coral cover than the lagoon and had very low coverage of sponges and soft coral. From the crest, the reef sloped down steeply to a sand flat at 30 m depth. The reef slope appeared to be divided into areas of high vertical relief separated by 'landslides' of rubble with sand. The reef slope had the highest percentage cover of hard coral (approximately 30%) and low numbers of sponges and soft coral. The southwestern portion of the island had a well-developed reef consisting of a huge bed of Acropora sp. interspersed by massive coral colonies. This reef is designated as reef 1 for further analyses. The depth ranged from 1-10 m at reef 1 and no substrate/lifeform data was taken at this site.

Olhugiri island is located on the northern edge of the outer ring of Thaa Atoll, approximately 2.35 N latitude, 73.05 E longitude. The lagoon of the atoll stretches approximately 50 m in each direction around the island. The northern side of the island is open to the sea and has a reef crest which slopes steeply down to 50 m where the slope becomes much gentler. The western portion of the island is lagoonal connecting to another island without any deep passages. The inner side of the island has a reef crest which slopes gently to about 10 m into a sand flat. The eastern portion of the island has a channel about 10 m in depth which allows passage of water into the atoll. The outer and inner reef crests were sampled for grouper density and diversity No quantitative habitat data was collected at Olhugiri.

Density and diversity of groupers: There was no correlation between any species abundance, nor total abundance, with depth (minimum, maximum, or mean) or time of day ($p > 0.05$) along the reef slope. There was a significant difference in the median number of grouper observed per transect between sites ($X^2 = 44.84$, df = 4, $p < 0.001$, Table 1). The slope at Gaagandu had the highest median density with 23 grouper observed per transect. Excluding the slope data, the other sites had no significant differences in the median number of grouper observed per transect ($X^2 = 4.74$, df = 3, $p > 0.05$). The lagoon at Gaagandu had a median density of 5 and the lagoon at Olhugiri 16. These two sites were not included in the density comparisons due to the low sample size (2 and 4 transects, respectively).

Figure 2: Substrata (a) and Lifeform (b) coverage of the site at Gaagandu Island, North Male Atoll. Open bars represent the slope area (n=100 1 m^2 quadrats), solid bars represent the reef crest (n=100), and striped bars represent the reef lagoon (n=40). (a) S = sand, RB = rubble, and HR = hard reef. (b) AT = algae, SP = sponge, SC = octocoral, and HC = hard coral.

a)



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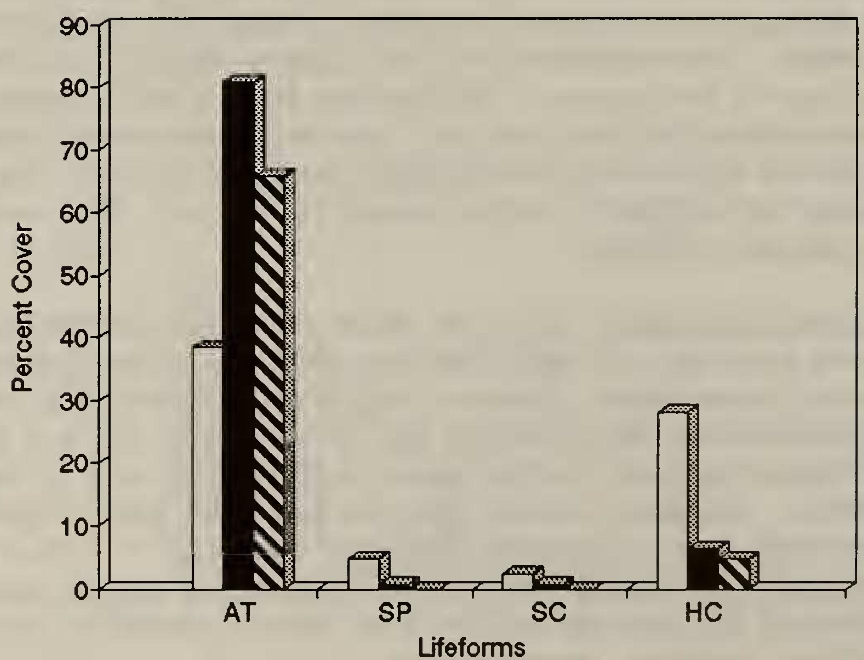


Table 1: Median, maximum, and minimum number of grouper observed per 240 m^2 transect within each zone at the two island sites.

	GAAGANDU			OLHUGIRI	
	CREST	SLOPE	REEF 1	INNER CREST	OUTER CREST
MEDIAN	7	23	9	10	11.5
MAXIMUM	13	50	18	24	15
MINIMUM	3	11	4	3	7

The lagoon at Gaagandu was characterized by low diversity (4 species). There were 7 species observed on the reef crest, dominated by Cephalopholis argus and C. urodeta (Table 2). Reef 1 was dominated by C. argus and Epinephelus merra. The slope had the highest diversity with 17 species (also the largest sample size). Cephalopholis miniata, C. leopardus, C. urodeta, E. spilotoceps, and C. argus dominated numerically in decreasing order of importance. Along the slope the densities of 'roving' species, such as G. albomarginata, Variola louti, and Plectropomus spp., were probably underestimated; these species were frequently observed swimming along the reef slope, but outside transect boundaries. Overall, the species of Cephalopholis tended to dominate numerically with many Epinephelus spp. being rarely observed. The Epinephelus groupers commonly observed (E. spilotoceps, E. merra, and E. macrospilos) were similarly colored, a white to cream background with brown spots or hexagonal markings.

The inner reef crest of Olhugiri had 16 species present and the outer reef crest 15. The dominant species on both reefs was C. argus, with a median number per transect of 7 inside and 6 outside (Table 2). C. leopardus and E. spilotoceps were the second most abundant species on the inner crest, whereas C. urodeta was second most abundant on the outer slope.

Length-frequency distribution: The majority of grouper observed in the lagoons at Gaagandu and Olhugiri were small (5-15 cm Total Length (TL)). No groupers were observed over 25 cm TL. The reef crest and slope had similar size - distributions ($X^2 = 7.07$, df = 3, $p > 0.05$). The < 5 cm and 5-15 cm categories were combined due to an expected value < 1 (Everitt 1992). The majority of grouper observed were 5-25 cm TL. On the slope the smaller grouper (5-15 cm) were dominated numerically by Cephalopholis leopardus and C. urodeta. The largest fish observed on the slope (> 35 cm) were Anyperodon luecogrammicus, Aetheloperca rogaa, C. argus, Variola louti, E. polyphekadian, and C. miniata. Fish observed were mostly less than 50 cm TL. Fish greater than 50 cm were mostly V. louti and P. laevis. The larger grouper observed on the reef crest (25-35 cm) were C. argus. Reef 1 had similar numbers of fish in the 5-15 cm, 15-25 cm, and 25-35 cm categories when compared to the other sites at Gaagandu ($X^2 = 0.43$, df = 2, $p > 0.05$). Reef 1 had a larger percentage contribution of the >

Table 2: Median and maximum number of groupers observed per transect (median, maximum) for Gaagandu slope (GS), Gaagandu crest (GC), Gaagandu lagoon (GL), Gaagandu reef 1 (GR), Olhugiri inside crest (OI), Olhugiri outside crest (OO). The minimum number observed per transect was zero except * = 3, + = 1, and # = 2. % = species observed outside boundaries of transects

SPECIES	GS	GC	GL	GR	OI	OO
Number of transects	48	11	2	12	13	6
Aethaloperca rogaa	1,6	---	---	---	0,1	---
Anyperodon luecogrammicus	1,4	0,2	---	1,2	0,2	---
Cephalopholis argus	3,11	3,7	---	5,9*	7,9+	6,9#
C. leopardus	4.5,16	---	---	0,1	1,6	0.5,1
C. miniata	5,17	---	---	---	0,4	---
C. sexmaculata	0,2	---	---	---	---	---
C. spiloparea	0,4	---	---	---	---	---
C. urodeta	2.5,18	1,8	---	0,1	0,2	3.5,7
Epinephelus caeruleopunctatus	0,1	0,1	---	0,1	0,1	0,1
E. fasciatus	---	---	%	---	---	---
E. fuscoguttatus	0,1	---	---	---	---	---
E. macrospilos	0,1	1,3	1,1	---	---	---
E. merra	---	0,3	3.5,5	1.5,6	0,2	---
E. ongus	0,1	---	0.5,1	0,1	---	---
E. polyphekadian	0,2	---	---	0,1	---	0,1
E. spilotoceps	3,11	0,3	---	0,3	1,4	0,1
E. tauvina	---	---	---	---	0,1	---
Gracila albomarginata	0,2	---	---	---	0,1	---
Plectropomus areolata	---	---	---	0,2	0,1	0,1
P. laevis	0,1	---	---	---	0,1	---
P. pessuliferous	---	---	---	---	---	---
Variola louti	0,2	---	---	---	---	---

35 cm category than the other sites at Gaagandu. These larger grouper were mainly C. argus with a few A. luecogrammicus.

There was a significant difference in the length-frequency distributions of groupers on the inner and outer crests at Olhugiri island ($X^2 = 12.51$, df = 4, $p < 0.05$). Many small (< 5cm) C. leopardus were observed on the inner crest, whereas only 1 < 5 cm C. urodeta was observed on the outer crest. There were more smaller (5-15 cm) grouper and fewer larger (25-35 cm) grouper on the inner crest than would be expected if the two size-frequency distributions were similar. Alternatively, there were fewer smaller (5-15 cm) grouper and more larger (25-35 cm) grouper on the outer crest than would be expected.

Similarity index: The similarity in species composition was compared using Jaccard's coefficient, which is based on species presence/absence data (Table 3). The reef slope at Gaagandu was most similar to reef 1 and Chicken Island (53%). The rest of the sites at Gaagandu were less than 50% similar, with the lagoon the least similar to the reef slope and reef 1. The Olhugiri reef crests were most similar to each other (82%).

Sample number: Seven species in the slope area had median densities greater than zero (Table 2). The median number of transects necessary for a reliable density estimate ranged from 2 to 16 (Table 4). The number of transects needed was related to the degree the species exhibited a clumped distribution as indicated by their I_d values ($r = 0.73$, $p = 0.06$). Two species, Anyperodon leucogrammicus and Aethelaperca rogaa, had I_d values which were not significant or nearly so; this indicated their dispersion patterns were not significantly different from random.
These species required only a few transects to determine their density. In contrast, the other 5 species showed various degrees of clumping and required more transects to reliably estimate their densities (Table 4).

For all species combined, the number of transects needed for an accurate survey ranged from 7 to 37 depending upon the level of accuracy desired for the median density and the percent of the species observed (Figure 3). Increasing the number of transects from 7 to approximately 15 provided a large increase in the accuracy of the median density estimate and percent of species observed. The accuracy of the estimate of median density increased from 20% to approximately 10% of the reference median density, while the percent of species observed increased from 70% to over 80%. Further increases in the number of transects provided more moderate increases in the accuracy of the median density estimate and percent of the species observed.

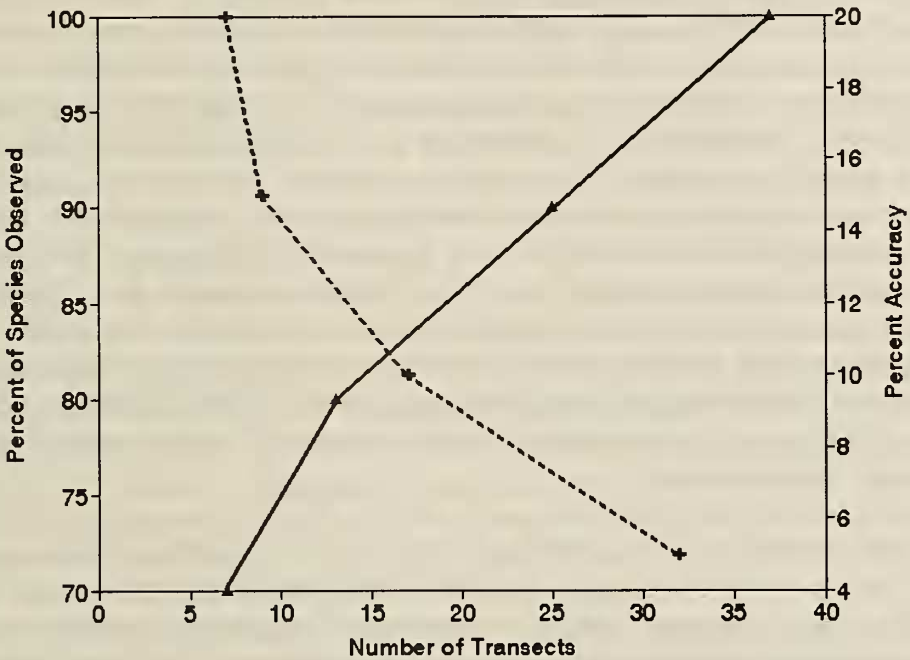
Table 3: Similarity matrix of Jaccard's coefficient comparing the presence - absence of species among survey sites.

SURVEY SITE	1	2	3	4	5	6	7	8
1. Gaagandu slope	1.00							
2. Gaagandu crest	0.33	1.00						
3. Gaagandu lagoon	0.11	0.38	1.00					
4. Gaagandu Reef 1	0.53	0.46	0.14	1.00				
5. Chicken Island	0.53	0.46	0.00	0.36	1.00			
6. Olhugiri inside crest	0.57	0.35	0.11	0.65	0.47	1.00		
7. Olhugiri outside crest	0.68	0.29	0.06	0.59	0.60	0.82	1.00	
8. Olhugiri lagoon	0.17	0.38	0.33	0.33	0.18	0.25	0.19	1.00

Table 4: Morisita's index of dispersion (I_d) in relation to the median number of transects necessary for a reliable density estimate for the 7 most common species of grouper observed in the slope zone at Gaagandu Island, North Male Atoll. Chi-square test statistics and associated probability levels indicate whether or not the species' dispersion pattern was significantly different from a random distribution.

SPECIES	MEDIAN NO. TRANSECTS	I_d	X^2	P
Anyperodon luecogrammicus	2	1.31	64.5	0.045
Aethaloperca rogaa	3	1.15	57.9	0.133
Cephalopholis spilotoceps	7	1.44	119.0	< 0.001
C. argus	11	1.47	111.4	< 0.001
C. miniata	12	1.34	136.9	< 0.001
C. leopardis	13	1.38	141.7	< 0.001
C. urodeta	16	1.91	220.0	< 0.001

Figure 3: Number of transects needed to obtain a desired level of accuracy in estimating the median number of groupers per unit area (dashed line) and percent of all species observed (solid line) on the slope at Gaagandu (reference values are 23 for median density and 17 for total number of species observed).



DISCUSSION

Habitat can be viewed on a number of different scales. The density and distribution of groupers were related to within and among zone differences in habitat type. First, at the macro-scale, there were clear differences in the density and diversity of groupers at Gaagandu Island between the lagoon, crest, reef 1, and the slope. The slope had a higher sampling effort so that rarer species were more likely to be observed. These different zones vary in the amount of refuge available for groupers. The lagoon and crest had little relief. The lagoon at Gaagandu has been mined for coral (M. Haleem pers. com.). The lagoon at Olhugiri has not been mined extensively and still has large coral heads. The density at the lagoon at Olhugiri exceeded all sites except the slope at Gaagandu. This indicates that the lagoon at Gaagandu probably supported a much higher density of groupers prior to mining. Reef 1 had high relief, but consisted mainly of dense thickets of Acropora sp., which might have limited their use by certain species as the interstices were probably too small for movement and hiding (the dense thickets most likely inhibited the efforts of the surveyor as well). Harmelin-Vivien (1977) found that spur and groove reefs at 6-18 meters depth had more species of fish and a higher biomass than the deeper sloping platform.

Within the different zones the species were associated, to varying degrees, with specific features. Some species had very little association with structural features of the zone such as the species of Plectropomus, Variola louti, and Gracila albomarginata. These species were observed to freely roam large areas generally > 15 meters deep. Variola louti was not observed in caves or hiding in the Society Islands, but swam off the bottom (Randall and Brock 1960). Gracila albomarginata was observed frequently in shallow water 5-10 m, however, Randall and Heemstra (1991) reported that this species was more abundant in depths greater than 15 m. This species tended to swim along the slope and did not appear to hide when frightened, but swam away, as is consistant with Randall and Heemstra's (1991) observations. Smith-Vaniz et al. (1988) also indicated that this species was an active swimmer, not resting on the reef substratum. Plectropomus areolata appeared more substrate attached; the younger ones were observed swimming among the Acropora thickets on reef 1. The species of Plectropomus feed mainly on fishes and tend to be less sedentary than most groupers (Randall and Hoese 1986). Aethaloperca rogaa tended to be intermediate between these free-roaming species and the more substrate attached species. Individuals tended to swim about freely, but would often hide under coral heads and ledges when approached. They did not traverse long distances as did the previously mentioned species, but would remain near a large coral structure in the water column.

The reef slope contained areas with high coral relief, in between which occurred 'landslides' of coral rubble and sand. Stoddart (1966) documented these same features of Maldivian reefs. These rubble patches were frequently inhabited by small Cephalopholis urodeta and, especially, Epinephelus spilotoceps. The latter species was usually observed on the edge of these rubble patches near high coral relief rather than out in the open. Epinephelus merra was abundant in the lagoons of the islands and at reef 1. This species is similar to E. spilotoceps, being a demersal carnivore living under ledges near the bottom of coral mounds and rubble (Hiatt and Strasburg 1960). E. merra is typically found in shallow water on patch reefs in lagoons and bays (Heemstra and Randall 1993). Many C. urodeta observed had a coloration with the posterior 1/3 to 1/2 of the fish black. Species descriptions of this fish indicate that the Indian Ocean variety has only a dark caudal fin, but that in "dark habitats" in the Comoros Islands it was uniformly brown (Randall and Heemstra 1991). Small specimens (< 10 cm) of C. urodeta were observed in shallow water that appeared uniformly black or with a red head region and black body posteriorly. Most of the individuals of this species conformed to the species description in Randall and Heemstra (1991), however many followed this pattern of more extensive black coloration on the posterior 1/3 to 1/2 of the body and the soft dorsal and anal fins. Cephalopholis urodeta is strongly demersal and rarely ventures away from shelter (Hiatt and Strasburg 1960). The most site attached of the slope species was C. leopardus. It was always seen within patches of coral with closely set 'finger' arrangements. When approached it would dart into the coral head. Anyperodon luecogrammicus was often seen in pairs. Cephalopholis sexmaculata was observed only in caves as is consistent with the observations of Randall and Ben-Tuvia (1983).

C. argus tended to have a higher density at shallower depths and dominated the diversity on the reef crest. This species is one of the most common food fishes (Randall et al 1985), and is generally one of the most abundant piscivores at most locations thoughout the Indo-Pacific (Randall and Ben-Tuvia 1983). It is more common on exposed rather than protected reefs (Randall and Brock 1960) and prefers depths of 1-10 m (Heemstra and Randall 1993). Shpigel and Fishelson (1989) found this species on the shallow reef table and reef wall in the Gulf of Elat. Harmelin-Vivien (1977) observed C. argus at depths of 6-18 m on spur and groove reefs and 18-25 m on the lower sloping platform at Tulear. Cephalopholis miniata is abundant in deep lagoons and dominates coral knolls that are isolated at depths of 17-33 m (Randall and Brock 1960). At one knoll off the slope at Gaagandu at 30 m depth, this species was the most numerous of the groupers observed. The grouper species observed on the reef crest and lagoon were in close association with structural features such as overhangs and crevices (with the exception of C. argus, which roamed about freely while darting into cover when approached). The species observed in the lagoon were all similarly colored (brown spots or hexagons on a light background) and tended to blend into the background of algal covered rubble. Hiatt and Strasburg (1960) found E. macrospilos under large coral heads and rock ledges, seldom far from cover. Our observations on this species in the lagoon at Gaagandu support their findings. Epinephelus fasciatus was observed in the lagoon closely associated with shelter. Fishelson (1977) observed this species near rocks in the lagoon of the Gulf of Eilat (Aqaba) as well as in the fore reef.

The number of transects required to adequately characterize grouper density and diversity is dependent upon the dispersion patterns and the desired levels of precision, accuracy, and percent of the species observed in the community. A single visit to a reef is not likely to record all species present, especially cryptic ones (Sale and Douglas 1981). An analysis similar to that conducted here could be done on a preliminary set of transects in order to determine the number of transects required. The number of transects should be determined not only by the dispersion patterns of the species of interest, but also by logistical constraints on effort. Collecting a large sample might increase accuracy minimally and use time that could be applied to other sites (Bros and Cowell 1987). In addition, if only species densities are required, the level of effort devoted to a particular species could be tailored to the degree to which a species is clumped. Only a few transects would be required to characterize the density of a randomly dispersed species, while a species which is clumped would require more transects.

The groupers observed in this study appeared to have specific habitat requirements or preferences. The dispersion of the groupers throughout the site is probably related to the dispersion of their preferred habitat. Cephalopholis leopardus is strongly substrate attached and its distribution was significantly clumped (Table 4). The clumped distribution of the species is likely due to a clumped distribution of its preferred habitat. Thirteen transects would be needed to adequately characterize the density of this species whereas a species such as Aethaloperca rogaa which had a random distribution (Table 4), would need only 3 transects. A. rogaa is a species which is not strongly substrate attached. However, our data on Anyperodon luecogrammicus does not follow this pattern as it was randomly dispered, but appears to be strongly substrate attached. A more detailed investigation of its habitat might reveal that it is a generalist in its association with the substrate.

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